"Thermodynamic Analysis of Processes for Hydrogen Generation by Decomposition of Water"

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Module 4: A Simplified Multisection Process for Thermochemical Hydrogen

Introduction

Module 1 of this series provides the foundation for thermodynamic analysis of processes for energy effects and process constraints. Module 2 provides experience with single-unit processes. Module 3 treats processes for thermochemical decomposition of water for hydrogen manufacture from an overall point of view. The present Module does an analysis of a water decomposition process involving 2 sections that exchange methane and methanol as well as heat. The objective is to gain experience in treating recycles and multiple sections involving reactions that can then be built on in Module 5 that analyzes the 3-section Sulfur-Iodine process.

We first repeat essential elements of Module 1. Figure 4.1 illustrates the concept for a steady-flow system, with inlet and outlet streams at specified absolute temperatures, T, pressures, P, and sets of molar or mass amounts for the components, {N}, along with energy that crosses the boundaries as "shaft work", W_s, and heat, Q. Note that if a stream has both vapor and liquid, its specification must include the amounts of components in the phases. For pure components, this means specifying either T or P, the total flow, N, and the quality or fraction of the system that is vapor, x. For mixtures, defining the state is more elaborate. The balance equations for steady flow processes are:

Figure 4.1. Steady Flow System for Applying Material, Energy, and Entropy Relations, Eqs. (4.1) and (4.2).

$$_{i}\ N_i h_i(T_i, P_i,\ x_{i})\quad _{i}\ N_o h_o(T_o, P_o,\ x_{o})\quad _{s} W_s\quad _{b} Q_b\quad Q_e\quad 0 \tag{4.1}$$

$$_{i}\ N_i s_i(T_i, P_i,\ x_{i})\quad _{i}\ N_o s_o(T_o, P_o,\ x_{o})\quad _{b} \frac{Q_b}{T_b} \tag{4.2}$$

the reactions in the sections connects the flows of these streams. This is not a necessary assumption, but significantly simplifies the analysis.

Figure IV.1. Simplified Schematic Diagram of Schulten Process for Thermochemical Decomposition of Water to Manufacture Hydrogen. Subscripts for species are A = Methanol,

Table 4.3 shows problem specifications for decomposing water by the Schulten process, with the streams and properties of Table IV.2 and $\boldsymbol{T_c}$ = 313K, and $\boldsymbol{T}_{21}$ = 491 K.

Table 4.3 Specific Problems for Case III. Bold = Specified; Italic = Solved. The Helium states are set at $\boldsymbol{T_{i1}}$